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Decoupling CO_2 emissions and industrial growth in China over 1993–2013: The role of investment

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ABSTRACT

Since industrial sector is a leading energy consumer and CO_2 emitter in China, the degree of the decoupling of CO_2 emissions and industrial growth plays a critical role in realizing the energy-conservation and emission-reduction goals of China. This is the first study to present a specific investigation on the decoupling of CO_2 emissions and industrial growth in China from 1993 to 2013. Using an extended logarithmic mean Divisia index (LMDI) model focusing on both energy-related and process-related CO_2 emissions and introducing three novel investment factors, i.e., investment scale, investment share, and investment efficiency, we highlight and explore the remarkable role of investment in the mitigation and decoupling of CO_2 emissions with industrial growth. The results show that China's industrial sector experienced the weak decoupling during 1993–2013. The investment scale is the most important factor responsible for the increase in CO_2 emissions and the inhibition of the decoupling. The investment efficiency effect has a volatile trend and overall, it plays the most significant role in reducing CO_2 emissions, followed by the energy intensity effect and process carbon intensity effect, whereas the energy mix, carbon coefficient, and investment share have marginal effects. Among 36 industrial sub-sectors, the seven factors of RCMCP (raw chemical materials and chemical products), NMP (nonmetal mineral products), and SPFM (smelting and pressing of ferrous metals) have significant effects on the decoupling. Thus, the three sub-sectors should be among the top concerns for abating CO_2 emissions. Finally, we provide policy recommendations considering both conventional and investment factors for China's industrial sector to realize emission reduction targets.

1. Introduction

With the increasing threat from global warming, the effect of economic growth on carbon dioxide (CO_2) emissions has received an international concern. Economic growth cannot be realized without energy consumption, whereas the continuous utilization of fossil fuel-based energy sources is the dominant factor of CO_2 emissions (Zhang and Cheng, 2009; Shao et al., 2011; Shahiduzzaman and Layton, 2015). The global CO_2 emissions have sharply increased to 32.3 billion tons in 2014.[1] To control global warming, the international community has been making efforts to mitigate CO_2 emissions and reached the first legally binding agreement on climate change – Paris Agreement – in December 2015. As the largest CO_2 emitter (8 billion tons of CO_2 in 2014[2]) among all countries, China has also actively undertaken this bounden duty of CO_2 mitigation. The Chinese government targets to hit the emission peak before 2030 and to reduce the CO_2 emissions per unit of gross domestic production (GDP) by 60–65% in 2030, compared with the 2005 level.[3] Such a declaration not only lies in China's international responsibilities and obligations, but also results from its domestic need of sustainable development.

However, China is encountering great pressure to implement emission reduction because it is undergoing a rapid industrialization and urbanization process characterized by massive energy consumption and thriving industrial production (Jiang and Lin, 2012; Xu and Lin, 2015). With the rapid economic development, China's energy consumption experienced a sharp increase from 825.9 million tons of coal equivalent (Mtce) to 2867.7 Mtce over the period 1993–2013, with an average annual rate of over 12%.[4] Correspondingly, China's energy-related CO_2 emissions rose at a high annual growth rate of 9%.[5] Besides, China's process-related CO_2 emissions increased at 10% annually.[5] The industrial sector is the essential pillar of China's economic growth, as

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[1] Source: International Energy Agency (IEA). See http://www.chinairn.com/news/20150316/150415113.shtml.

[2] Source: International Energy Agency (IEA). See http://news.163.com/15/0315/13/AKOI8JIT00014AEE.html.

[3] Source: See http://www.cpnn.com.cn/zdzgtt/201411/t20141113_764916.html.

[4] The data of China's energy consumption are gathered from China Energy Statistical Yearbook (1991–2014).

[5] The CO2 emissions are calculated using the method by IPCC (2006), and the detail will be described in Section 2.4.

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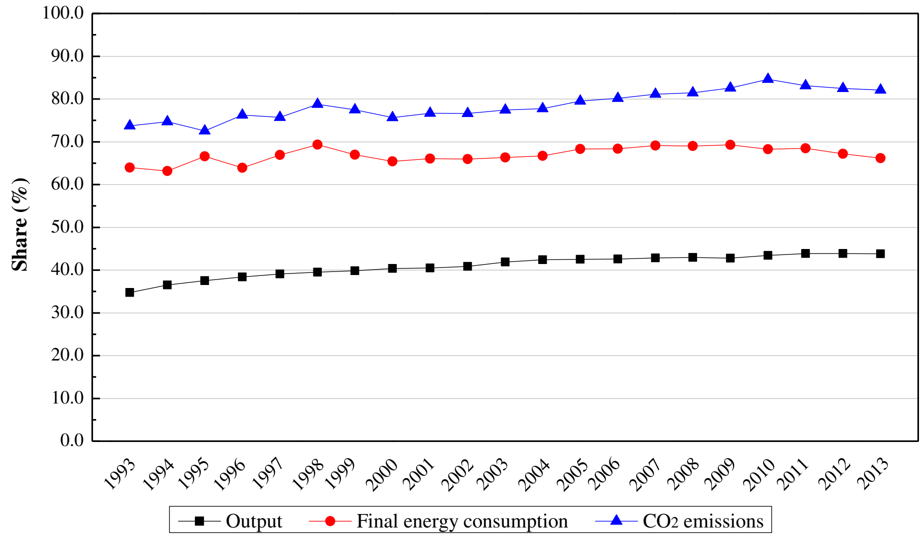

Fig. 1. Share of industrial sector in the GDP, final energy consumption, and CO_2 emissions of China.

well as a leading energy consumer and CO_2 emitter. As shown in Fig. 1, the industrial sector accounted for 35–44% of GDP (at constant 2000 price), with more than 63% of final energy consumption and more than 73% of CO_2 emissions in China over 1993–2013. On annual average, the industrial energy consumption rose by 6.6% from 1993 to 2013, with a sharp annual growth of 7.1% in CO_2 emissions.[6] Due to booming heavy industry and extensive development mode, China's industrial sector has been in a continuous great demand for energy sources.

With respect to industrial energy consumption structure (see Fig. 2), fossil fuels have been playing the dominant role and the coal-type consumption share is the largest due to China's energy endowment, while non-fossil energy, such as hydropower, thermal power, nuclear power and other renewable energy, share a relative small proportion with a slow upward trend. Such a coal-dominated energy mix in China's industrial sector has caused a large amount of CO_2 emissions and thus huge destruction to the environment for a long time. Given consideration to both China's economic development and CO_2 reduction targets, decoupling industrial growth from CO_2 emissions is the key aspect for the emission mitigation in China's industrial sector or even the whole China.

The issue of decoupling CO_2 emissions and economic growth has already attached scholars' attention. Tapio (2005) investigated the decoupling of CO_2 emissions and economic growth in the transport sector of the EU15 countries during 1970–2001, and presented an earlier theoretical framework for decoupling. He found that the whole EU15 experienced expansive negative decoupling, expansive coupling, and weak decoupling in the 1970s, 1980s, and 1990s, respectively. De Freitas and Kaneko (2011) studied the decoupling of CO_2 emissions and economic growth in Brazil over 1980–1994 and 2004–2009, and explored the driving forces of CO_2 emission changes. Their results showed that the decoupling for the period 2004–2009 was relatively more significant and 2008–2009 experienced absolute decoupling, which was largely attributed to the carbon intensity reduction and energy diversification. Andreoni and Galmarini (2012) assessed the decoupling relationship in Italy from 1998 to 2006 and found that the Italian economic growth experienced relative decoupling form CO_2 emissions. Taking into account sectoral dimension, they gave a detailed explanation for the factors influencing CO_2 emission changes in the Italian various economic sectors. Enevoldsen et al. (2007) analyzed the decoupling of CO_2 emissions from industrial energy consumption and industrial growth in the energy-intensive industries in Scandinavia during 1993–2001, and they pointed out that the decoupling occurred most frequently in Denmark, while inverse decoupling and coupling appeared in several industrial sectors in Sweden and Norway.

Regarding China, the exiting studies are mainly concerned about the decoupling for the whole China, a certain region's industrial sector, or some industrial sub-sectors. For example, Liang et al. (2013) focused on the decoupling performance between economic growth and environmental pressure including CO_2 emissions for China during 1992–2012, and they found that CO_2 emissions were relatively decoupled to economic growth and that mining and manufacturing industries were two main sources of CO_2 emission growth. Zhang and Da (2015) studied the decoupling of CO_2 emissions and economic growth in China from 1996 to 2010, and the results suggested that in most years China witnessed the relative decoupling, to which the energy intensity and final energy consumption structure were two main contributors. Lu et al. (2015) concerned about the decoupling of industrial growth and carbon emissions in Jiangsu Province of China, and they discovered that there was a weak decoupling state from 2005 to 2012. Combined with factor decomposition analysis, they pointed out that the industrial output growth was the largest driver of the increase of Jiangsu's industrial carbon emissions. Ren and Hu (2012) aimed at China's nonferrous metals industry and analyzed the decoupling of CO_2 emissions and industrial growth in the period 1996–2008. They found that this sector went through four decoupling stages starting from strong negative decoupling and ending at weak decoupling.

To the best of our knowledge, studies related to the decoupling for the entire industrial sector in China are absent. However, since the industrial sector plays a critical role in the energy-conservation and emission-reduction plans of China, it is necessary to conduct a comprehensive investigation on the decoupling of CO_2 emissions and industrial growth, which is what the rest of the paper aims to achieve. Regarding the methodology, existing studies about the decoupling are frequently combined with decomposition analysis since the decoupling indicator itself cannot identify the real effort which certain countries need to take to realize a particular goal (OECD, 2002; Diakoulaki and Mandaraka, 2007; De Freitas and Kaneko, 2011). The factorial decomposition method helps depict the CO_2 emissions under various scenarios and to identify the drivers of emission changes as well as the influence mechanism. In general, the changes of energy-related CO_2 emissions are decomposed into several related factors. Nevertheless, the CO_2 emissions from industrial processes have not been fully explored in most existing decomposition analyses (e.g., Hammond and Norman, 2012; Tian et al., 2013; O'Mahony, 2013; Vaninsky, 2014; Ma, 2014; Zhang and Da, 2015; Malik

[6] The data of China's GDP and industrial share are derived from China Statistical Yearbook (2014); energy consumption data are from China Energy Statistical Yearbook (1991–2014); and CO2 emissions are estimated based on IPCC (2006).